

bacteria or the supply thereof is interrupted at a point when the denitrifying bacteria are increased.

5. The biological denitrification method for wastewater, as disclosed in Claim 1, Claim 2, Claim 3 or Claim 4, characterized in that the denitrification process is to treat with a granular medium and to control the amount of the supplied organic carbon source by an increase or decrease in the height of layers of the medium, which occurs by the increase or decrease of the denitrifying bacteria.

#### Detailed Description of the Invention

This invention pertains to a method for biologically treating and purifying organic wastewater such as sewage, excrement, industrial wastewater and other types of wastewater. In particular, this invention pertains to a biological denitrification method for wastewater using denitrifying bacteria adhered on a medium at a denitrification process.

This biological denitrification method is divided into two types: an activated sludge process; a biological fixed bed method used by adhering microorganisms onto granular, lump, plate, net, rod, fibered or tube media. At a treatment facility having a limitation on the installing area, the fixed bed method that is capable of purely keep nitrified bacteria and denitrifying bacteria at a high concentration and of minimizing the size of the device is put to the actual use. A denitrification treatment using a conventional fixed bed method is applied as follows. After a nitrogen compound in wastewater such as  $\text{NH}_4$  has usually been nitrified to  $\text{NO}_2$  or  $\text{NO}_3$  (henceforth referred to as  $\text{NO}_x$ ) at a nitrification step,  $\text{NO}_x$  is reduced and degraded (denitrified) to  $\text{N}_2$  at a denitrification step wherein a fixed layer or a fluid layer is formed by a medium with denitrifying bacteria

adhered. Since the treatment for excess bacteria generated with this method recycles the medium, after the medium has been removed from the denitrification step, bacterium bodies adhered onto the medium and the medium are separated so as to return the medium to the denitrification step and dehydrate, dry and burn the bacterium bodies. As the adhesiveness of the bacterium bodies against the medium is significant with the method, a high energy is required for a peeling operation. In addition, since the peeled bacterium bodies are purely cultivated, they demonstrate extremely low dehydrating performance. There is also a method to separate bacterium bodies from a medium by solubilizing the bacterium bodies on the medium by an anaerobic digestion means. Nevertheless, this method requires a long period for solubilizing the medium and a retreatment for a digestion supernatant liquor. Such conventional treatment methods for excess bacteria use complicated operations and have disadvantages to cause an anxiety to the industry. In particular, improvement of the treatment method for excess denitrifying bacteria is a crucial issue. The reason for it is that the amount of the denitrifying bacteria to be grown is 0.4 bacterium growing amount/ $\text{NO}_3\text{-N}$  (g/g) even in the case of methanol denitrifying bacteria having a lower bacterium body yield in comparison with that of nitrifying bacteria to be used is 0.1 bacterium growing amount/ $\text{NH}_4\text{-N}$  (g/g), which indicates 4 times higher than the amount of nitrifying bacteria per nitrogen to be removed.

The present invention is produced to eliminate these disadvantages of prior art methods and aims to offer a biological denitrification method for wastewater that is capable of applying an efficient denitrification treatment and of extremely readily and economically treating excess denitrifying bacteria without removing the bacterium bodies from the denitrification step and separating them from the medium.

The invention is a biological denitrification method characterized as follows. By treating the amount of an organic carbon source to be supplied at a denitrification treatment system having multiple denitrification steps serially connected by alternately adjusting an amount sufficient to grow the denitrifying bacterium bodies with an amount insufficient to grow zero to more denitrifying bacteria, methanol of the denitrifying bacteria grown on the medium due to a denitrification reaction by methanol (an external respiration denitrification reaction) is reduced. More specifically, excess denitrifying bacteria grown on the medium due to a denitrification reaction (an internal respiration denitrification reaction) that uses the components of the denitrifying bacteria per se as a reducing agent are reduced. After the reduction of the excess denitrifying bacteria, the nitrifying bacteria are grown again due to the denitrification reaction by methanol. Using these this method at multiple nitrification steps, the amount of the denitrifying bacteria at the entire steps is maintained at a specific amount.

The working example of the invention is described next based on the drawing. A whole body or a part of  $\text{NH}_3$  containing wastewater 1 is nitrified to  $\text{NO}_3$  at a nitrification process 2. Nitrified water 3 containing  $\text{NO}_3$  alone directly flows into a denitrification process 4 along with methanol 6. The major portion of  $\text{NO}_3$  is denitrified while the remaining part is denitrified without methanol 6 at a denitrification process 5. After the completion of the denitrification, the wastewater is discharged as treated water 7. In this case, the entire wastewater 1 or a part of wastewater 1 directly flows into denitrification process 4 through a bypass flow passage 1' as needed for treatment.

On the other hand, the denitrifying bacteria grow due to a denitrification reaction by methanol at denitrification process 4 whereas the bacteria gradually decrease due to an

internal respiration denitrification reaction at serially continued denitrification process 5, which uses the components of the bacteria per se as a reducing agent. The denitrifying speed of the internal respiration type is about 1/5 to 1/10 of that by methanol 6. Accordingly, if the amounts of bacteria at denitrification processes 4 and 5 are equivalent, an efficient denitrification treatment is achieved by then removing an 80 to 90% NO<sub>x</sub> and removing a remaining 20 to 10% NO<sub>x</sub> at denitrification process 5. The amount of denitrifying bacteria at the whole denitrification processes is quantitatively maintained by repeating the following operation. Before the denitrifying bacteria at denitrification processes 4 and 5 excessively increase or decrease, the supply of methanol 6 at denitrification process 4 is interrupted or reduced. A denitrification is carried out by supplying methanol 6 at denitrification process 5. Before the denitrifying bacteria at denitrification processes 4 and 5 excessively increase or decrease again, the supply of methanol 6 at denitrification process 5 is interrupted. A nitrification is carried out again by supplying methanol 6 at the previous process at denitrification process 4.

The grown bacteria can be reduced by reducing the supplying amount to an amount insufficient to grow the bacteria at the denitrification process not always without completely stopping the supply of methanol 6. However, the reducing speed becomes slower than that without the methanol supply, which is effective when the bacteria at the denitrification process are generally fewer.

The purpose of the denitrification process is achievable if at least two nitrification processes are serially connected. Three or more processes by further connecting a denitrification process 8 after denitrification process 5 at the end stage are preferred when

the amount of methanol to be supplied and the amount of bacteria at each process are adjusted.

Methanol 6' can be supplied at denitrification process 8 or post-processes at the end stage as needed.

The switching of the supply or stop of methanol can be manually operated by visually observing the increase or decrease of the amount of the denitrifying bacteria adhered on the medium. In this case, as for a means to identify the amount of the organic carbon source insufficient for growth of the denitrifying bacteria during the visual observation, the insufficient amount is determined based on the individual's experiences by looking at the amount of the denitrifying bacteria adhered on the medium. If the amount is sufficient, the amount of the bacteria increases to grow the biological film. In turn, if the amount is insufficient, the biological film becomes smaller so as to be contracted. Thus, the flow out of the bacteria along with discharge water can be identified. For example, when small-scale wastewater is treated, the growing amount is observable from the outside as it is used from outside and as a transparent or semi-transparent plastic structure is used at the denitrification process. When a structure using an opaque material such as a steel plate is used, a window so as to be provided to a sand filtering column or the like is attached on the side surface of a nitrification column in a vertically long fashion to observe the amount of the denitrifying bacteria grown in the column.

While the amount of the denitrifying bacteria in the column is observed using the method as described above, the supplying amount of the organic carbon source insufficient to grow the denitrifying bacteria is experimentally determined. In other

words, the supplying amount of the organic carbon source can be reduced as the amount of the denitrifying bacteria gradually decreases or the supply can be stopped.

In particular, the amount insufficient for growth refers to a sufficient amount if the bacteria grow by adding the organic carbon source or an insufficient amount if the bacteria do not grow. It is determined by the economic change. More specifically, it is determined how the bacteria change at a next period based on the bacterium conditions at a certain period. Accordingly, it is determined as a sufficient amount if the bacteria increase at the next period more than the previous period and if the biological film grows. If the bacteria decrease and if the biological film is at an instable condition, it is determined as an insufficient amount. When the medium is a granular type, the height of the medium layer increases or decreases by the increase or decrease of the amount of the denitrifying bacteria grown on the medium. Because of this, if this increase or decrease is detected using a surface (solid-liquid surface) meter by transmittance or other means, the supply or non-supply of methanol is controlled by an unattended means. In addition, the medium can be intermittently transferred by setting the medium transferring time using a timer. In this case, an optimal transferring time can be set based on the individual's experiences by increasing or reducing the height of the layer that fluctuates by the set time.

The amount of the bacterium bodies and the amount of denitrification at each denitrification process is controlled by adjusting or controlling the distribution of the methanol supply process and the methanol non-supply process and the increase or decrease of the amount of methanol to be supplied simultaneously or separately.

When the amount of the organic carbon source supplied is alternately adjusted to the amount sufficient to grow the denitrifying bacteria or the amount insufficient to grow zero or more denitrifying bacteria, the adjustment is preferably made at at least another denitrification process separately. The organic carbon source is supplied at a point when the denitrifying bacteria at the denitrification process are reduced. When the denitrifying bacteria increase, the supply of the organic carbon source is stopped or reduced.

As described above, because of the control of the amount of the organic carbon source added corresponding to the growing amount, the amount of the bacteria at the denitrification process can be kept within a proper range, thereby eliminating an inconvenience expected to occur during an operation not having the control. More specifically, the denitrifying bacteria excessively grow in the denitrification column where the organic carbon source is sufficiently supplied during the operation to separate from the medium or be discharged outside the column along with the medium, thereby blocking the pipe or increasing the treatment water solid. When denitrifying bacteria excessively grow at the denitrification process where the organic carbon source is sufficiently supplied, NO<sub>x</sub> to flow in is entirely denitrified. As a result, the denitrification column at the next stage completely becomes an anaerobic state to corrode and terminate the denitrifying bacteria (particularly when the water temperature is higher), thereby deteriorating the quality of the treatment water. Once the denitrifying bacteria are killed, it takes a large number of days to grow the denitrifying bacteria again. During the period, methanol is not used to further deteriorate the treatment. However, the invention does not demonstrate any of these disadvantages.

According to the invention, by alternately adjusting the amount of the organic carbon source to be supplied to the amount sufficient to grow each of denitrifying bacteria or the amount insufficient to grow zero or more denitrifying bacteria at each denitrification process at serially connected multiple denitrification processes, methanol of the denitrifying bacteria grown on the medium due to the denitrification reaction by methanol (the external respiration denitrification reaction) is reduced. In other words, excess denitrifying bacteria grown on the medium are reduced due to the denitrification reaction that uses the components of the denitrifying bacteria per se as a reducing agent. After this operation, the denitrifying bacteria are grown again by the denitrification reaction by methanol. With this method at multiple denitrification processes, the amount of the denitrifying bacteria at the whole processes is kept at a specific amount. Thereby, treatment equipment for the bacterium bodies is not required, such as a separator for excess bacteria, a dehydrating device, a dryer, an oven and the like. The purification efficiency of the denitrification treatment water also significantly improves to make the treatment operation simple so that only a valve operation is required for treating the excess bacteria. The operational management is also easier. The denitrification treatment water is purified at the same time when the excess bacteria are treated, thereby eliminating disadvantages of prior art methods associated with the treatment and disposal of the excess denitrifying bacteria to obtain a significantly improved denitrification treatment. The treatment cost for the excess bacteria is not required, methanol is also reduced due to the internal respiration denitrification, and the treatment cost is greatly reduced.

A working example of the invention is described next.

Testing device:

Fluid layer type denitrification column: 50ℓ; two cylindrical columns

(φ 200 mm; 1600 mm height; 50.2ℓ effective volume)

Testing conditions:

Testing wastewater: artificial nitrified solution NO<sub>3</sub>-N; 30 mg/ℓ

(Adjusted by adding NaNO<sub>3</sub> to dechlorinated tap water)

Amount of wastewater treated: 2000ℓ/day

Fluid layer medium: sand

The amount of the fluid layer bacteria increases or decreases by the height of the fluid layer.

The height of the fluid layer at the beginning of the testing:

Primary column: 600 mm

Secondary column: 1000 mm

The amount of methanol supplied at the beginning of the testing:

Primary column: 130 g/day

Secondary column: 0 g/day

Testing result:

Elapsing days (days)	Primary column			Secondary column		
	Amount of methanol supplied (g/day)	Treatment water NO <sub>3</sub> -N (mg/day)	Height of the fluid layer (mm)	Amount of methanol supplied (g/day)	Treatment water NO <sub>3</sub> -N (mg/day)	Height of the fluid layer (mm)
(Please refer to the original description)						

Note: An arrow (→) indicates the switching of the supply of methanol from the primary column to the secondary column or the secondary column to the primary column on the 20<sup>th</sup>, 40<sup>th</sup> and 50<sup>th</sup> days.

#### Brief Description of the Drawing

The drawing is a flowchart illustrating a working example of a method of the invention.

1...Wastewater

2...Nitrification process

3...Nitrification water

4, 5 and 8...Denitrification processes

6 and 6'...Methanol

7...Treatment water

The figure is not available.

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Chisato Morohashi